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Monika Dittrich, Stefan Bringezu

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Monika Dittrich[a,*], Stefan Bringezu[b]

The physical dimension of international trade Part 1: Direct global flows between 1962 and 2005

[a] Independent scientist, Heidelberg, Germany

[b] Wuppertal Institute for Climate, Environment and Energy, Research Group Material Flows and Resource Management, Wuppertal Institute, P.B. 100480, 42004 Wuppertal, Germany

[*] Corresponding author. Tel. +49 6221 71 99 725; e-mail: Monika.Dittrich@gmx.net

The Physical Dimension of International Trade, Part 1: Direct Global Flows between 1962 and 2005

Abstract
The physical dimension of international trade is attaining increased importance. This article describes a method to calculate complete physical trade flows for all countries which report their trade to the UN. The method is based on the UN Comtrade database and it was used to calculate worldwide physical trade flows for all reporting countries in nine selected years between 1962 and 2005. The results show increasing global trade with global direct material trade flows reaching about 10 billion tonnes in 2005, corresponding to a physical trade volume of about 20 billion tonnes (adding both total imports and total exports). The share from European countries is declining, mainly in favour of Asian countries. The dominant traded commodity in physical units was fossil fuels, mainly oil. Physical trade balances were used to identify the dominant resource suppliers and demanders. Australia was the principal resource supplier over the period with a diverse material export structure. It was followed by mainly oil-exporting countries with varying volumes. As regards to regions, Latin America, south-east Asian islands and central Asia were big resource exporters, mostly with increasing absolute amounts of net-exports. The largest net-importers were Japan, the United States and single European countries. Emerging countries like the 'Asian Tigers' with major industrial productive sectors are growing net-importers, some of them to an even higher degree than European countries. Altogether, with the major exception of Australia and Canada, industrialized countries are net-importers and developing countries and transition countries are net-exporters, but there are important differences within these groups.

Keywords: International trade, physical trade volume, physical trade balance (PTB), material flow analysis (MFA), physical economy.

1. Introduction

International trade is usually described in monetary terms. But monetary terms show only one side of the coin; the other side, the physical dimension of the traded commodities, is - again - gaining increasing importance. Since David Ricardo the physical characteristics of commodities from producing and consuming countries form the basis for understanding international trade. The interpretation of monetary measurements of real trade is also complex due to monetary policies of the nations and fluctuations of international commodity prices. Until now, physical units to describe trade flows were mainly only used for selected goods like cereals and metal commodities. For most other goods, the physical dimension of international trade was not known. Data on the physical dimension is, however, needed when the shipping volume of international trade is to be determined, and moreover, when the domestic material consumption (DMC) or the total material consumption (TMC) of countries and the related resource productivity are to be monitored (OECD, 2008a). The information is also needed from a global perspective, for example to identify resource suppliers and consumers on the global market and to estimate the resource flows between countries and groups of countries.

On a country level, physical trade flows have so far been calculated mainly for Latin American and European countries and recently for some selected countries from Asia (e.g. Amann et al., 2002; Schütz et al., 2003; Bringezu et al., 2004; Eisenmenger et al. 2005; Eisenmenger, 2008; Giljum, 2003; Giljum et al., 2008; Moriguchi and Hashimoto, 2006; Perez-Rincon, 2006; Russi et al., 2008; Weisz et al., 2005; Xu and Zhang, 2007). Physical trade flows have mainly been analyzed as part of the material flow indicators of national or regional economies. OECD (2008b) provides an inventory of country activities towards this end. However, a comprehensive perspective on the physical dimension of world-wide trade is still lacking, because important countries are still missing. Furthermore, calculation methods and databases of the known trade flows often differ. This hampers the comparison of results and an estimation of physical world trade.

This article describes a method to calculate complete physical trade flows for all countries which report their trade to the UN. The method is based on the UN Comtrade database and it was used to calculate worldwide physical trade flows between 1962 and 2005 for all reporting countries in nine selected years. The central aim of this article is to provide information about the method and to give an overview of the empirical findings of the direct physical flows on a global level.

2. Database and Method

The mass specifications of traded commodities are needed to calculate physical trade flows and physical trade balances. Contrary to the monetary values of traded goods, data concerning the physical dimensions are largely incomplete in national and international statistics. The most comprehensive collection of international trade flows is the United Nations Commodity Trade Statistics Database (UN Comtrade). It covers trade statistics from 1962 to the most recent year reported by the statistical authorities of close to 200 countries or regions. In total, it contains more than one billion records. The United Nations explicitly requests that countries report the weight of all traded commodities (UN Department of Economic and Social Affairs, 1998). But even in UN Comtrade around 20 % of all records do not include information about the traded mass. Around three quarters of the missing data relate to the mass quantity at the most differentiated commodity group level. The remaining missing data is the sum of the physical quantities within the hierarchical structured commodity classification system. Completeness of the datasets as well as degree of differentiation vary from country to country and from year to year. For example, trade statistics from European or South American countries are usually differentiated and complete whereas trade statistics from African Countries or small islands are often insufficient and undifferentiated.

Until now, three basic approaches have been followed to deal with the problem of missing physical information: (1) neglecting missing values, (2) estimating them based on national sectoral statistics and (3) estimating missing values based on other statistics and datasets.

The first approach was chosen for example by Xu and Zhang (2007) to calculate Chinese trade. They used national trade statistics which provided the weights for the major flows of imports and exports, “whereas other minor flows having only monetary data were ignored” (Xu and Zhang, 2007: 124). The crucial question here is how large of an error neglecting those ‘minor’ or light flows might cause. Based on our results on UN Comtrade, this approach would neglect between 5 and 20 % of annually traded mass flows on a global level, although the range differs between the countries. Most European and South American countries report their physical trade flows relatively completely, so that less than 1 % of the physical trade flow would be missed. African, Asian and North American countries often very incompletely report their trade flows to UN Comtrade; the missing trade flows could reach up to 50 % of their total trade flows.

The second approach – calculating missing trade flows using national sectoral statistics - was used for example by Schütz et al. (2003) in their study of European burden shifting. The authors used EUROSTAT trade data. This method is possible if there are sufficient national statistics which are reliable and structured in the same, or in a similar commodity classification system, as the trade statistic. The method is viable if only a small amount of mass data is missing and if domestic production of the relevant products do not significantly differ from traded products (as is the case in EU trade). But this method is limited if national statistics are poor, or even not available, or if the classification systems are too different. Many countries do not provide sufficient national statistics, especially those where they are badly needed. On a global level, this method is not feasible in a reasonable amount of time or personnel resources. Using UN Comtrade, between 8,000 and 40,000 values from different national statistics would have to be researched for each year.

An example of the third approach is the calculation of Saudi Arabia's and the USA's physical trade flows by Eisenmenger et al. (2005: 21). The authors used UN Comtrade, classification SITC-1, level commodity classes (3-digits-level). In UN Comtrade, physical values are normally aggregated up to the commodity class, if physical values are reported. The authors re-calculated the data in cases of statistical frictions or gaps by extrapolating trade flows when there was a linear trend of trade or by averaging the data of the adjacent years. In the case of major missing datasets, they calculated so called 'theoretical' product prices. Then they divided the monetary value of the product group by the average price of the 'theoretical' product prices to calculate the missing mass of the traded product groups. This method also has a number of disputable implications. One of the most crucial points is how the authors calculated the theoretical product prices. Although they did specify the applied procedure, the uncertainties seem significant with regard to the heterogeneity of the product groups treated in this way. It is also not clear what products and how many of them the authors used to calculate a 'theoretical' price. For example, for a product group like "machines for special industries" including paper and pulp mill machinery, printing machinery or food processing machines or for a product group like "road motor vehicles" including busses, passenger motor cars, motorcycles, trucks and road tractors. These are typical product groups within the USA's trade statistics without reported mass flows where the authors had to calculate a theoretical price. A second major point may seem to be unapparent at first glance, but it has some far-reaching consequences: Trade statistics are formed hierarchically. In other words, the most differentiated product level (so-called subheadings or 5-digits) is summed up to the next higher level (4-digits) and so on. Calculating trade flows starting with the available mass values of commodity classes (3-digit-level) implies that trade flows which are reported on the more differentiated levels (4- and 5-digit-levels) without mass are omitted. Thus, the authors missed all unreported physical flows which are not integrated within the given physical value of the corresponding commodity classes. On a global level, the missing physical flows on the 4- and 5-digits levels are more relevant than the missing values on the 3-digit-level and make up between 3 and 12 % of global physical trade. In addition, physical trade flows that are as differentiated as possible are necessary for analyzing the material composition of flows and combining them with coefficients. Trade statistics are mainly ordered by the degree of processing. However, some material characteristics can only be distinguished on the 4- and 5-digit levels, for example in SITC-1-Classification there is a commodity class including all non ferrous base metal ores and concentrates (copper, tin, lead, zinc, aluminium, etc.). Thus, ignoring the more or most differentiated levels in trade statistics in the beginning could result in loosing opportunities to disaggregate flows and combine them with more differentiated coefficients.

The choice for one data source or another is also a critical issue. The three mentioned examples are based on different trade statistics: national statistics, EUROSTAT and UN Comtrade. Trade statistics vary in their classification systems and in included and excluded trade flows because of national security issues. This may result in problems regarding the comparability of trade statistics. However, this problem is not just limited to different data sources, but could also be critical within one database. For example, using older classification systems like SITC-1 within UN Comtrade to calculate actual trade flows, like Eisenmenger et al. (2005) did, could produce false results. Since 1990, the majority of countries report their trade in SITC-3 or SITC-4. UN Comtrade converts reported trade data into older classification systems, but without adjusting them in every detail. It "may occur that some of the converted commodity codes contain more (or less) products than what is implied by the official commodity" (http://comtrade.un.org/db/help/uReadMeFirst.aspx).

These examples illustrate some of the methodological and data based problems that can occur when physical trade flows are compared. Of course it becomes more difficult if no explicit information about the used method is given (e.g. Perez-Rincon 2006). As a consequence, the calculated physical trade flows are hardly comparable between countries and are insufficient to estimating global physical trade.

Thus, contrary to a country-by-country-solution, we developed a world-wide approach to calculate the global physical flows of all countries. In the following, the main idea and the central information about the method are summarized (detailed information is given by Dittrich, 2010). The UN-Comtrade database was used, with the Standard International Trade Classification (SITC-1 until 1990, later SITC-3). We included all trade data that countries reported over their trade with the partner "world", altogether between 600,000 and 1 million records each year. The approach is based on the calculation of the average global annual price per kilogram for each commodity group. For most of the commodity groups there is information about the weight and for every record there is information about the monetary value. First, the average price per kilogram p for each commodity group i for each year y was calculated on the basis of the sum of the prices P and masses M of all traded commodities where mass information is given by the countries c:

$$(1)\ p\,(iy) = \sum P\,(iyc) \,/ \sum M\,(iyc)$$

This average price p was used to calculate the missing physical information of the traded commodity group i not given by the countries C.

$$(2)\ M\,(iyC) = P\,(iyC) \,/\, p\,(iy)$$

This calculation was carried out for each commodity group starting at the most differentiated level (5-digit-level). Then, the mass information was summed up to the next level according to the classification structure, country by country, year by year, and separated by the trade direction. The procedure was repeated on this more aggregated level and the totals were calculated to the next higher level, and so forth up to the aggregated sum of each trade flow for each country and year.

In some years, and for very few commodity groups (less than 1 % on the most differentiated level), there was no information about physical flows, e.g. watches and clocks or orthopaedic appliances. For that reason, it was impossible to calculate an average global price p for that year. But to our favour, sufficient mass information for each commodity group was given by countries in the years 1962 and 2005. Thus, it was assumed that the average price development was linear, and the missing physical flows of these commodity groups were calculated by interpolation.

In total, the procedure was applied for the years 1962, 1970, 1975, 1980, 1985, 1990, 1995, 2000 and 2005. The calculation includes all countries which reported their trade to the UN, i.e. 82 countries in 1962 and 161 countries in 2000, with between 110 and 140 countries in the other years. In general, the original data was used. Original information was only omitted if it was obviously wrong, for example for outliers like cereal prices of more than 300 US$ per kilogram or if countries had mixed kilogram and karat units when reporting their diamond trade. The implementation of this proceeding was programmed in *mysql. Mysql* is an open-source software for databases recommended when the quantity of records culminate in several millions (www.mysql.com). The result is a database which contains several million records of physical flows covering each commodity group on each and every hierarchical level within the given classification system.

The advantage of this method is clearly the comparability between the countries on the different aggregated and disaggregated levels. Another advantage is the applicability, especially for those countries lacking national statistics. Furthermore, it is compatible to the common global trade statistics and descriptions based on monetary units. But of course, this method has its own limitations. Using global average prices may lead to an underestimation of mass flows for the commodity groups of a country that is mainly trading cheaper products within this commodity group. And it may result in an overestimation of mass flows for the commodity groups of a country that is principally trading high price products within this commodity group. It may also produce inaccurate estimations if the world prices of the commodity groups have strongly varied between years.

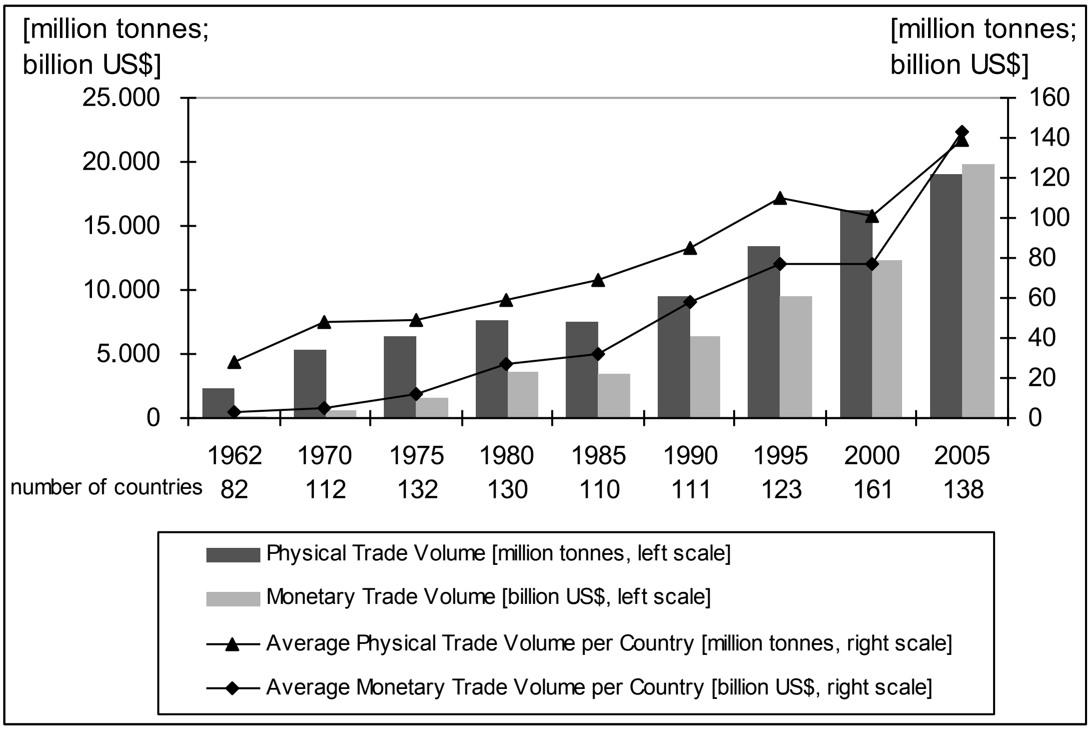
Two examples exemplify the possible effects and thus the limitations of this method when analyzing flows on a differentiated level: durum wheat (S3-0411) with a ‘world price’ and high quantities of trade flows and tropical wood (S3-24751) with a wide range of prices between the countries, but with minor trade flows. The average price of durum wheat was 0.15 US$ per kilogram in 2000, based on 92 % of all countries that reported mass and monetary values within that year. 90 % of traded durum wheat cost between 0.13 and 0.17 US $ per kilogram. Prices outside this range are mainly found by countries with a trade volume of durum wheat lower than 1,000 t. Tajikistan was one of the biggest importers of durum wheat in monetary terms without reporting the mass in 2000. Counting with the average price, they imported around 242,000 t. The plausible range lies between 279,000 t (with a price of 0.13 US $) and 213,000 t (with a price of 0.17 US $). That means, if Tajikistan imported durum wheat at the lower average price, flows were underestimated by around 37,000 t (15 % of the estimated average); if they imported durum wheat at a higher average price, the flows were overestimated by around 29,000 t (12 %); if they imported at the average price of Russian exports (0.14 US$ per kilogram), the flows were underestimated by 17,000 t (7 %). In total, Tajikistan imported 2.1 million t. Thus, the possible over- or underestimations of Tajikistan’s imports could sum up to 1.5 % of the total imports, compared to between 213,000 and 279,000 t, or up to 10 % of imports, which would otherwise be neglected when not accounting for durum wheat. In the second example, the average price of tropical timber (29 different forest species, amongst other teak, jongkong and tiama) was 0.22 US$ per kilogram in 2000, based on 95 % of all countries that reported mass and monetary values. 80 % of all traded tropical wood cost between 0.10 US$ and 2 US $, with average prices outside this range again mainly found in countries with a low trading volume in monetary and physical terms. Israel was one of the dominant importers of tropical timber in monetary terms without reporting the mass. According to the method chosen, Israel imported 27,470 t of tropical wood. If the country imported nothing but high price tropical wood (within the 80 % range), the imports were overestimated by 24,000 t (89 % of the estimated average). If Israel imported only the low price tropical wood, the imports were underestimated by 32,500 t (120 %). In total, the possible over- and underestimation changes Israel's total imports of around 40 million t by less than 0.1 %. Looking at the global level and the total sum of country trade flows like we do in this paper, those over- and underestimations do not change the numbers in a perceptible way. But one should consider these limitations when analyzing trade flows of single products or of countries on a more disaggregated level.

In general, the lack of detailed information concerning the single products subsumed in the commodity groups and the exact dates of their prices per physical unit will always limit the exact estimation of all physical flows. Nevertheless, in the sum of all physical flows on a country and global level, these over- and underestimations may compensate each other and altogether probably carry no weight. However, when analysing the flows of single commodities it is advisable to consult further national or sector-oriented statistics. This is particularly important for resources or products with a wide range of prices and is less important for resources or products with a global market price. It is more advisable for products which are reported by a minor number of countries and it is less crucial for products or product groups for which almost all countries report the traded mass.

3. The Physical Dimension of the Global Trade Volume

The global physical trade volume has been growing since 1962 (Figure 1). It reached more than 19 billion tonnes in 2005. As the trade volume per definition accounts for the sum of both imports and exports, the real trade flow equals half of the reported trade volume (counted: (imports + exports) / 2). Thus, in 2005 nearly ten billion tonnes passed an international border. In 1962, important countries like Australia did not yet report their trade to UN Comtrade; hence global trade volume is under-estimated. 5. 4 billion tonnes were traded in 1970. Between 1970 and 2005 trade volume has been growing by a factor of 3.5. The average physical trade volume of a country was about 140 million tonnes in 2005. Since 1970, it grew by a factor of 2. 8. The moderate decline in the year 2000 was caused by a higher number of small countries and islands reporting their trade.

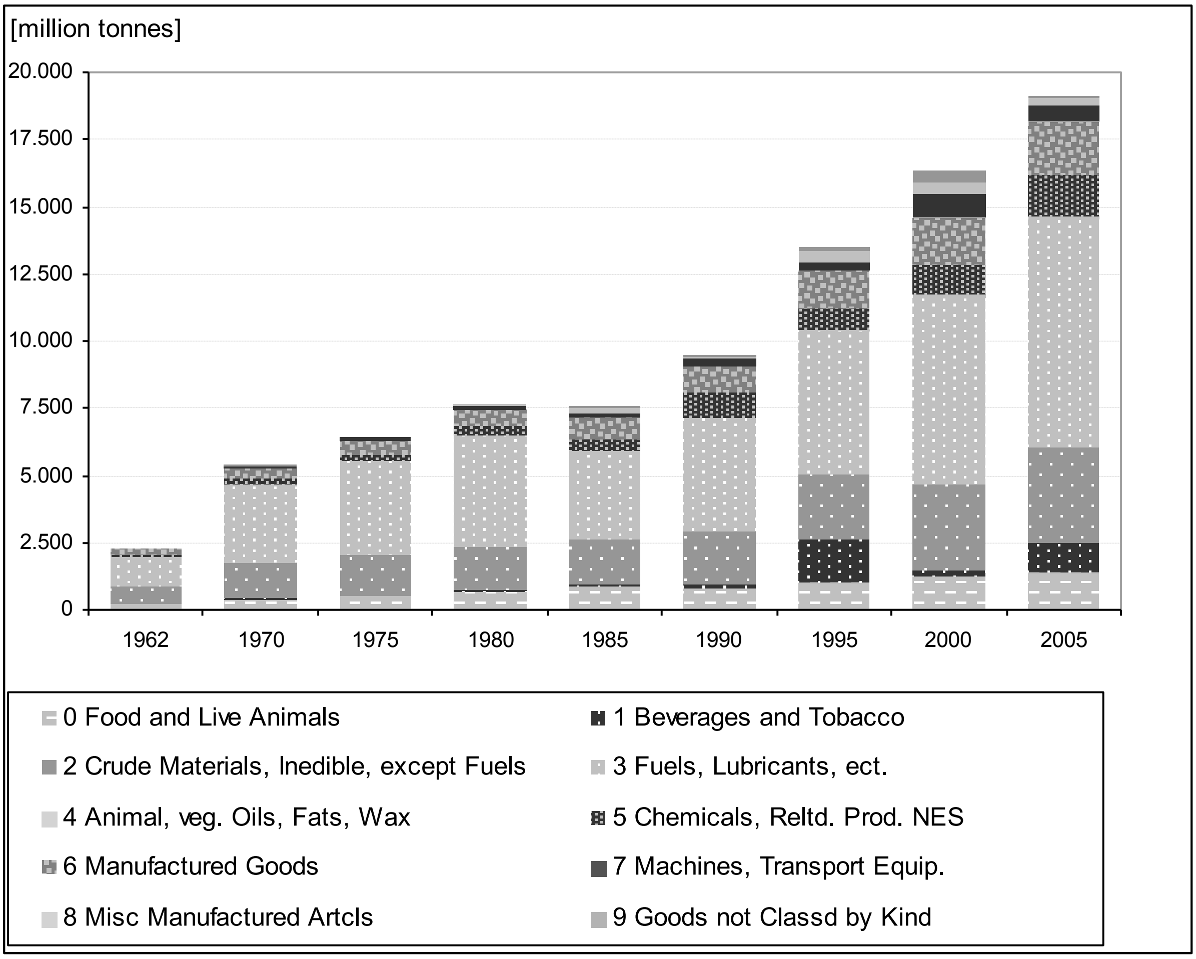
Physical trade volumes increased significantly less than monetary flows. In monetary terms, global trade volume increased approximately thirty-five fold since 1970 and the average trade volume per country grew by a factor of 28. The difference in growth rates between monetary and physical terms might be explained by inflation, increasing quality and a higher share of manufactured goods. In monetary terms the share of manufactured goods increased from 62 % to 74 % between 1970 and 2005; the dominant groups were machines and transportation equipment.



Source: own calculation, based on UN Comtrade (current prices). The number of countries varies according to the number of reporting countries.

Figure 1: Global trade volume in physical and monetary terms, 1962 - 2005

The dominant commodity group in physical trade has been fossil fuels, with a declining share of about 55 % (1970) to 45 % (2005) of all trade (Figure 2). In 1970, non-energetic raw materials ranked second (25 %), but have become less important since then with 19% in 2005. The share of manufactured goods increased from 13 % in 1970 to 24 % 2005. In 1995 and 2005 China reported exports within the product group “Waters, including natural or artificial mineral waters and aerated waters” of 738 million tonnes, respectively 832 million tonnes, to UN Comtrade. These water exports are responsible for the large quantities in the group beverages and tobacco in those two years. Because other countries also reported exports within this product group, although not to such a high degree, the data for China’s exports have been retained unchanged. It will be singled out when necessary to maintain comparability.

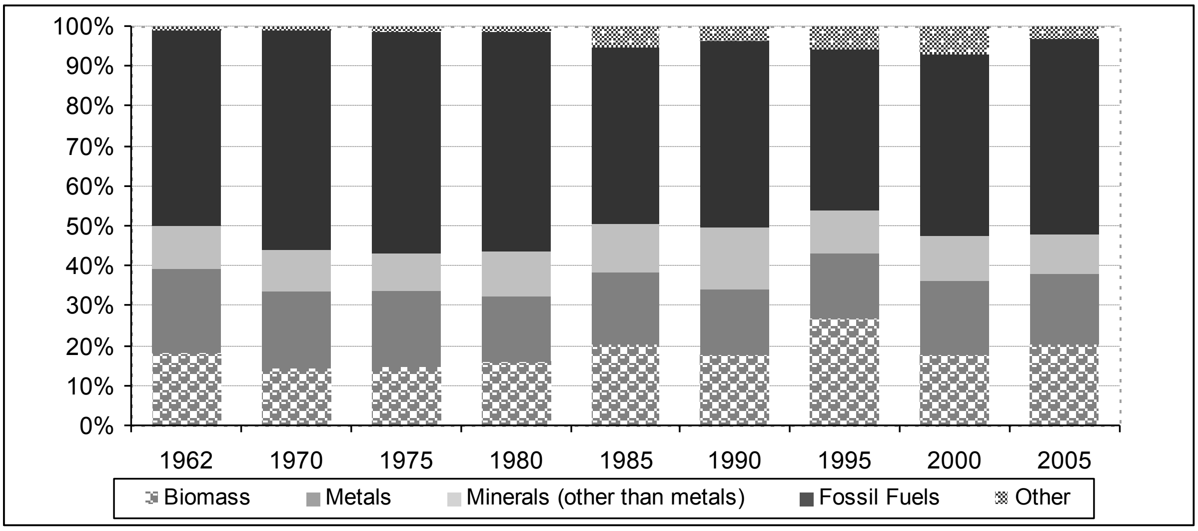


Source: own calculation, based on UN Comtrade

Figure 2: Physical trade volume by trade classification, 1962 – 2005

The dominance of fossil fuels within international trade can also be observed when analysing the material composition of the commodity groups (Figure 3). The main categories are biomass[1], metals, non-metallic minerals and fossil fuels. For example, the category 'Fossil fuels' includes commodities like plastics and bicycles belong to the category 'Metals'. The category 'Other' includes mainly non-relatable categories like antiques. Changes between years are to a great extent caused by the composition of the reporting countries. For example, in 1962 oil-exporting countries are under-represented. By and large, the composition of world trade has been rather constant, but since 1970 a decline of fossil fuels and derived commodities and a slight increase of biomass based products can be observed.

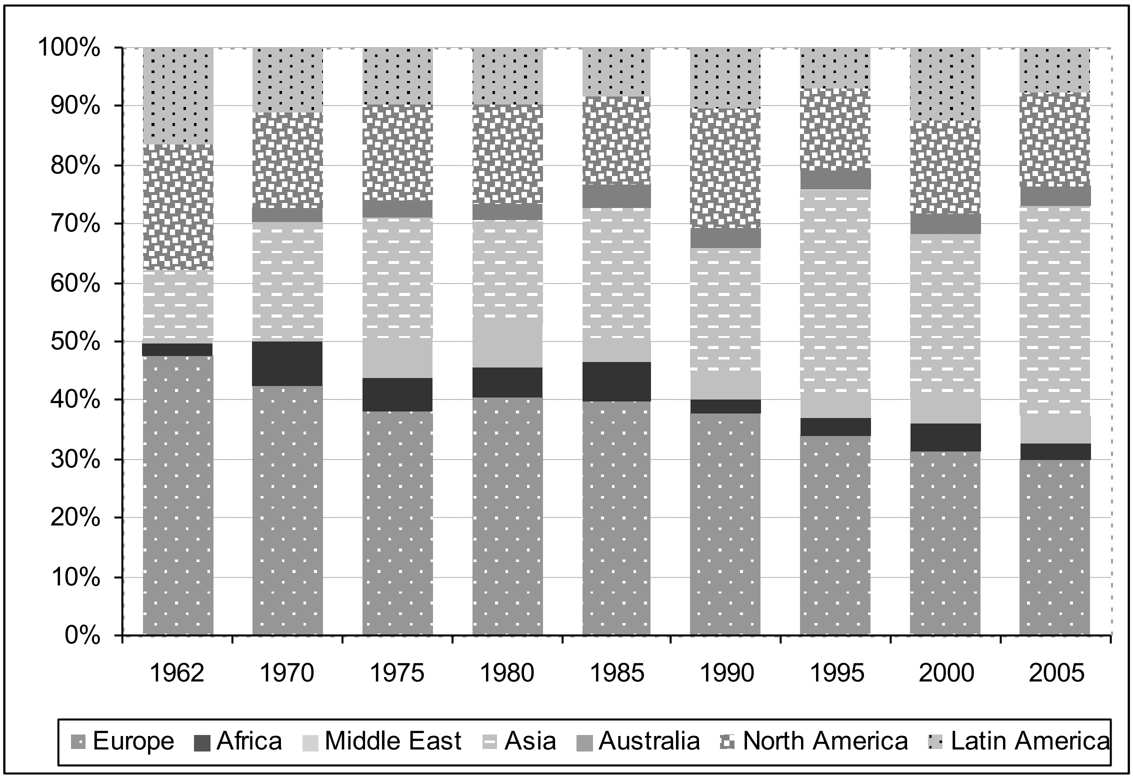
[1] Within this study, biomass is accounted for as actually traded weight, and not converted into dry matter.



Source: own calculation, based on UN Comtrade and Schütz, personal communication

Figure 3: Physical trade volume by material composition, 1962 - 2005

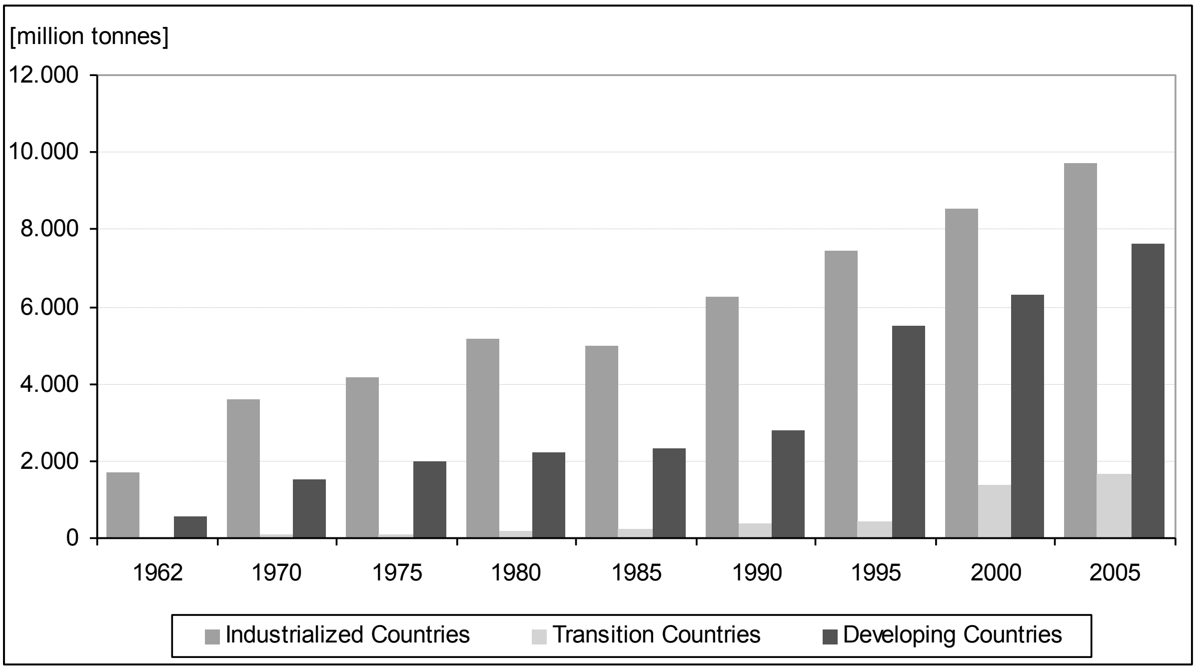
The declining importance of European countries in favour of Asian countries is clearly visible (Figure 4). While during 1970 around 43 % of the physical trade volume was traded by European countries, their share declined to 30 % in 2005. On the other hand, Asian countries' proportion increased from around 22 % in 1970 to 35 % in 2005. North America's share of the trade volume has been overall constant since 1970; it averages 17 %. The fluctuation of Latin America's share depends mainly on Mexico. Excluding Mexico, the share of Latin America has been around 8 % and relatively constant since 1970.



Source: own calculation, based on UN Comtrade

Figure 4: Physical trade volume by region in %, 1962 - 2005

Trade volume from developing countries increased from 1.5 billion tonnes in 1970 to 7.6 billion tonnes in 2005 (Figure 5). Trade volume from the countries Brazil, Mexico, China, India and South Africa reached around 1.6 billion tonnes in 2005. From 1970 to 2005, the share of developing countries in physical trade increased from 28 % to 40 %. In 2005, industrial countries still made up about half of the physical global trade, which is much less than the 64 % measured in monetary terms.



Source: own calculation, based on UN Comtrade

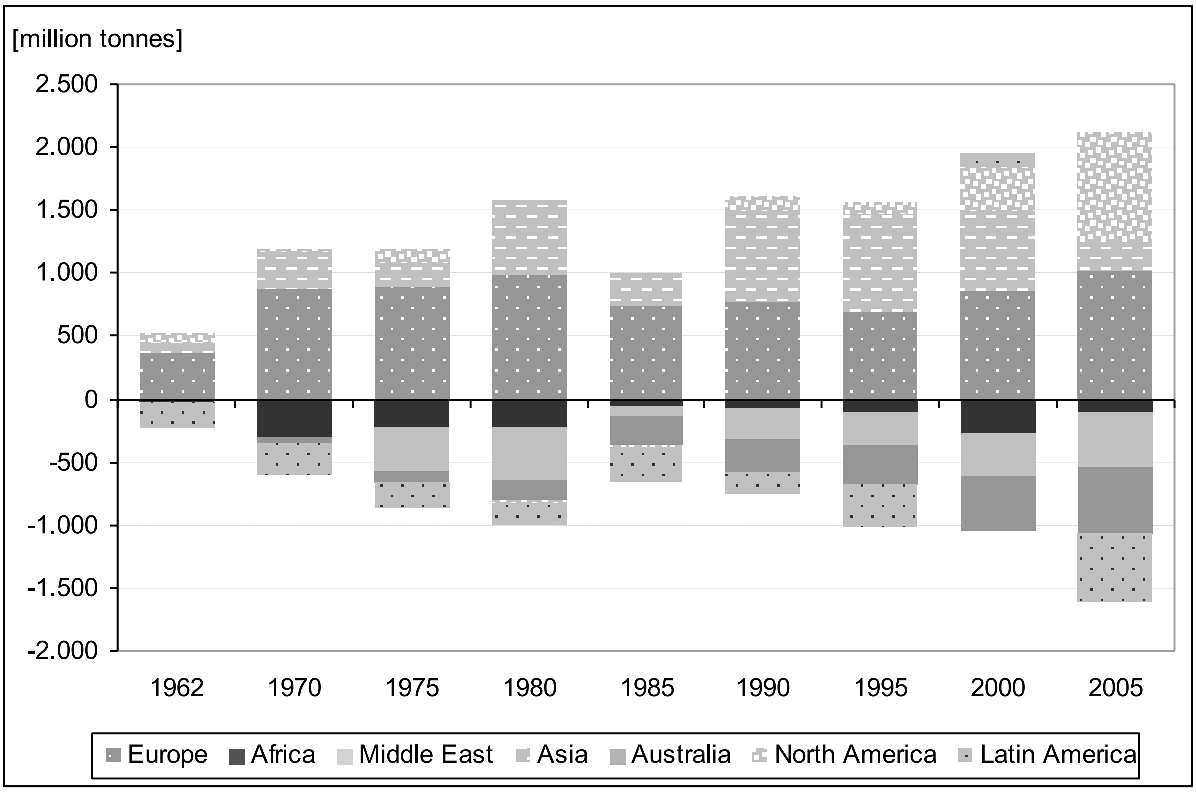
Figure 5: Physical trade volume by developing category of countries, 1962 - 2005

4. The Physical Trade Balances

Physical trade balances (PTBs) account for the difference between the masses of all imports and exports. They form part of the system of material flow indicators, which are used to measure the physical basis of economies. Unlike monetary trade balances, physical trade balances are calculated by subtracting imports from exports. The PTB provides information as to whether a country depends on resources from other countries (import surplus) or supplies the global demand (export surplus) (OECD, 2008a). Like monetary trade balances, the PTB is an aggregated indicator which provides information on the sum of trade flows. PTBs can be detailed according to their material components to provide information about the material structure of resource supply and they can be related to other indicators, e.g. national extraction or resource endowment, for assessment. Additionally, the direct physical flows can be weighted by the ecological rucksacks or the indirect flows of the traded commodities, which indicates to what extent a country is shifting environmental burden to another country (e.g. Bringezu et al., 2003 and 2004). Indirect flows of trade, explanation and interpretation are complex issues; part II of this article will discuss indirect trade flows in detail, which may change the overall trade balance of resource use completely. This section will focus on the world wide physical trade balances of direct, unweighted flows.

Figure 6 shows the PTBs differentiated by region. Theoretically, the positive and negative columns are supposed to be balanced, but they are not. The main reason for this is the number of countries that did not report their trade to UN Comtrade, especially from Africa, Asia and the Middle East which are probably resource exporting countries. The figure clearly shows that Europe and Asia were the regions with net-imports of resources during all the years, and because Europe is a higher net-importer than Asia, it is the region which most depends on resources from other countries in absolute terms. The increasing net imports of North America since 1990 reflect the increasing net imports of the United States.

Looking at the net exporter side, it can be observed that Africa, the Middle East, Australia and Latin America are the regions which supply the world market with resources. The positive trade balance of Latin America in 2000 was caused by an extraordinary import surplus from Mexico. The amount of net-exports from the middle-east region varies depending on the countries reporting their trade to the UN (especially Iran and Iraq; both countries did not report during wartime).



Source: own calculation, based on UN Comtrade

Figure 6: Physical trade balances by region, 1962 - 2005

The regional proportion of net-imports reflects the declining role of European Countries within the world trade market and a rising share of North America's net imports. The proportion of Asia's net-imports is minor compared to its share in trade volume while the rising proportion of Australia's net exports is higher than its proportion in trade volume.

The regional distribution of the physical trade balances of different countries can be seen in the maps for the years 1970 and 2005 (Figure 7 and 8). These years were selected to give an impression of the main changes in physical trade flows. In 1970, countries in Western Europe, North America and Japan were clearly the dominant net-importers of resources, with medium and small resource importers mainly located in Europe. As regards developing countries, there were few net-importers in 1970. Besides the 'Tiger States', Pakistan, Sudan and Uruguay were examples of developing countries with a demand for resources. The dominant resource suppliers were oil-exporting countries (Venezuela, Iran and Algeria). Australia, Indonesia and Canada also supplied the world market to a large extent with resources. Medium net-exporters were found in Latin-America and coastal Africa. Countries with a balanced PTB mostly traded only to a small extent, like for example Guatemala, Madagascar and Afghanistan.

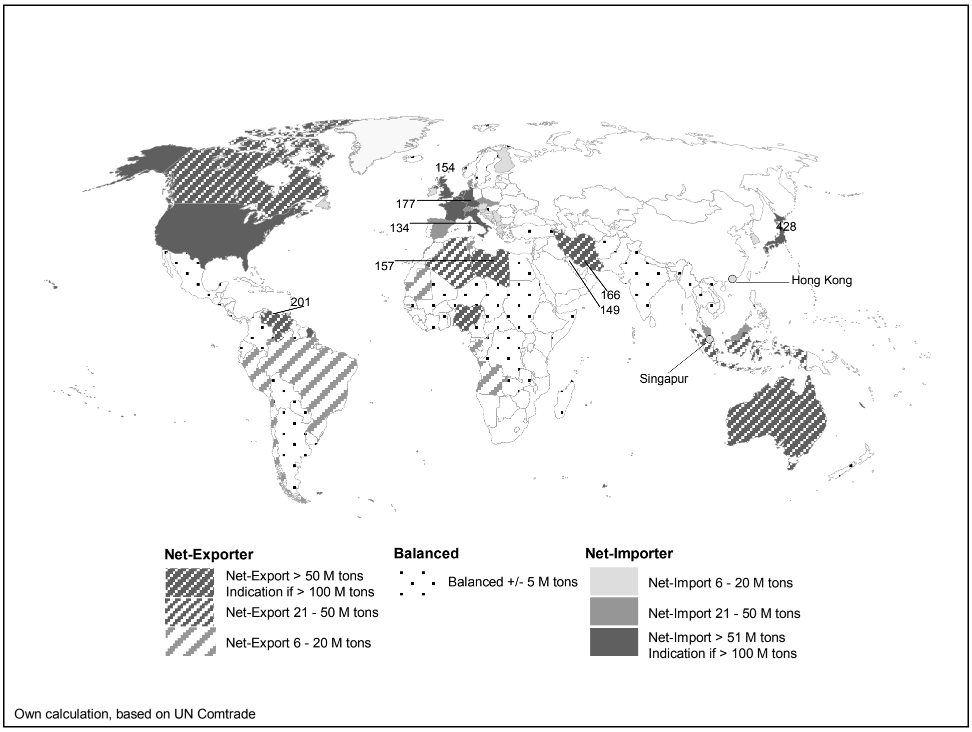


Figure 7: Geographical distribution of world suppliers and demanders of resources, 1970

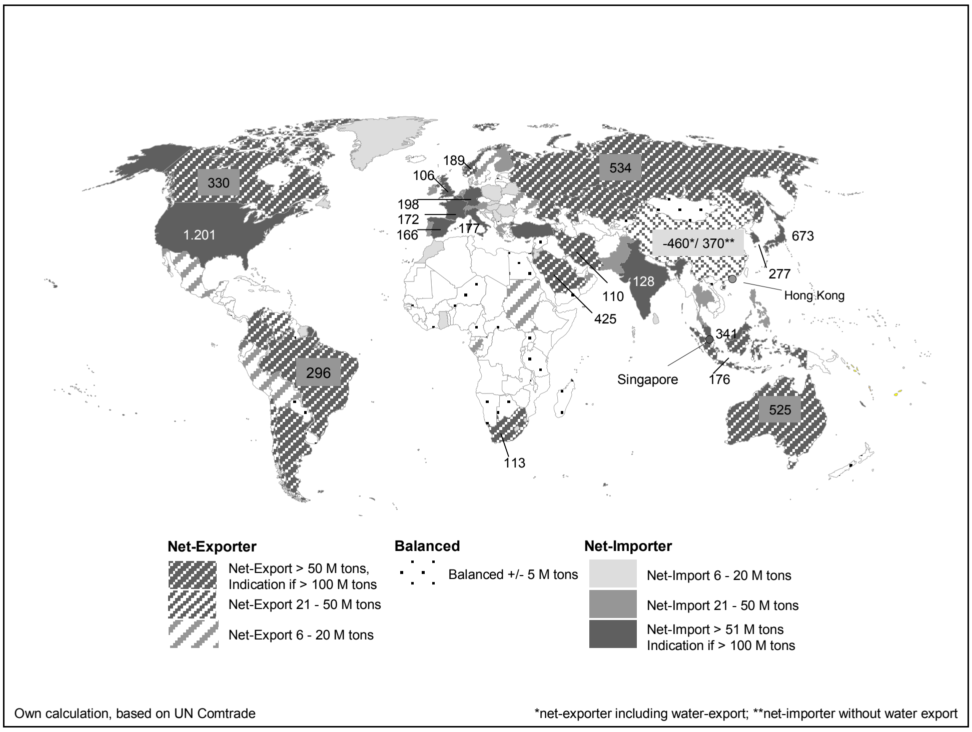


Figure 8: Geographical distribution of world suppliers and demanders of resources, 2005

In 2005, in general, the role of the countries in the world market as resource suppliers or resource demanders had not changed much: Western Europe, Japan and the USA were still among the biggest net-importers (Figure 8). The main suppliers were still Australia, Canada and oil-exporting countries. South American countries and Indonesia remained suppliers, although with a higher share compared to 1970. Most of the African states still had a balanced trade in absolute physical terms.

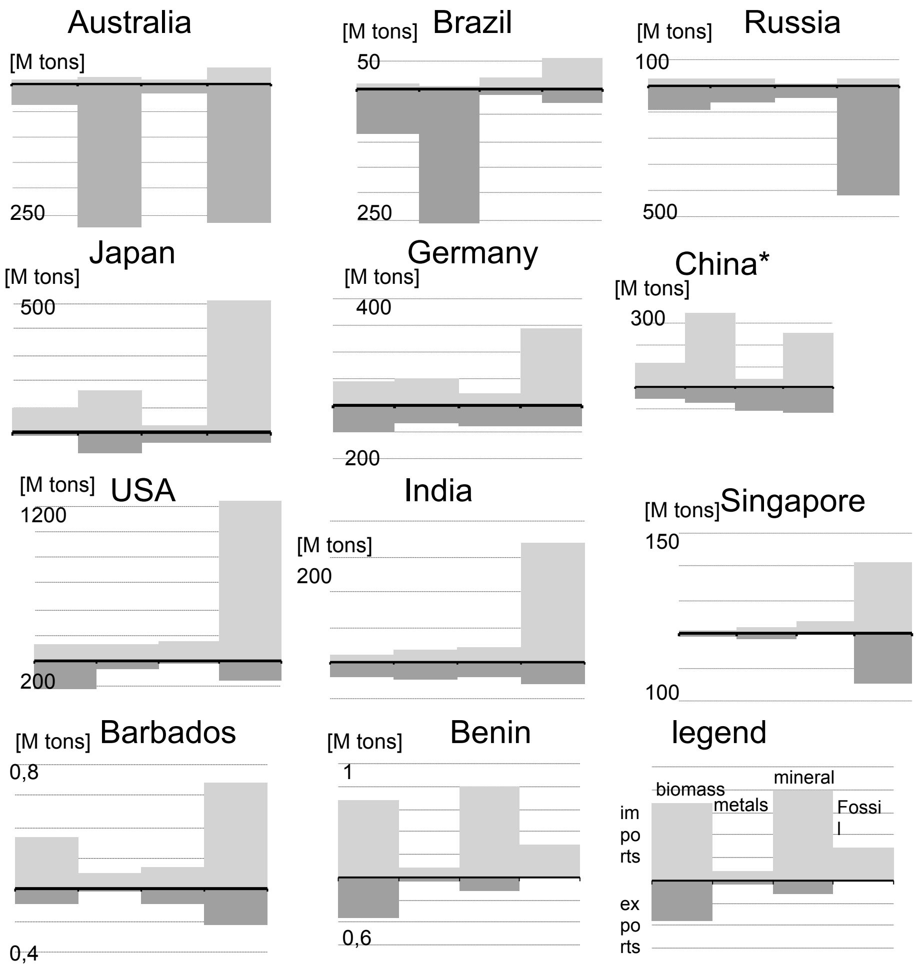
But there have also been some obvious changes: It can be seen that emerging countries like South Korea, Malaysia, India and China (without counting the water exports to surrounding city states) have become dominant resource demanders with net-imports partly exceeding the net-imports of European countries. Islands which are mainly specialized in international financial services have - besides the emerging countries – had the highest growth rates in net imports. The most important increases in the amount of the absolute physical trade balance took place in about thirty net-exporters and net-importers, while the other countries have remained relatively constant.

Figure 9 shows the material profiles of trade for selected countries in 2005. The first line shows some dominant resource suppliers: Australia and Brazil with a diverse export-structure and Russia as an example of countries with a specified export structure. Australia’s exports were composed equally of metals and fossil fuels (coal), while it imported only fuels (oil) in a noteworthy amount. Brazil mainly exported metals and in addition some biomass, while its imports were primarily fossil fuels. Russia’s exports were foremost fossil fuels (gas and oil); its structure is also very typical of oil exporting countries.

In the second line there are examples of countries with important production activities which are reflected in the trade structure. Japan and Germany mainly imported fossil fuels, but both countries also imported metals for manufacturing in a noteworthy amount. China’s imports were dominated by metals; it is important to notice that China reported water exports in an extraordinary amount during 2005 (830 M tonnes) which are taken out in the figure.

The third line contains examples of countries which despite distinct differences also have some similarities. The USA was exceptional in regards to high consumption and thus net imports of fossil fuels. The magnitude of metal flows was similar to the trade of Japan and Germany, whereas it is interesting to see a higher net import of minerals (other than metals) in the USA. In addition, the USA has been a relevant exporter of farming products (cereals) to supply the world. Also India’s and Singapore’s imports were clearly dominated by fossil fuels.

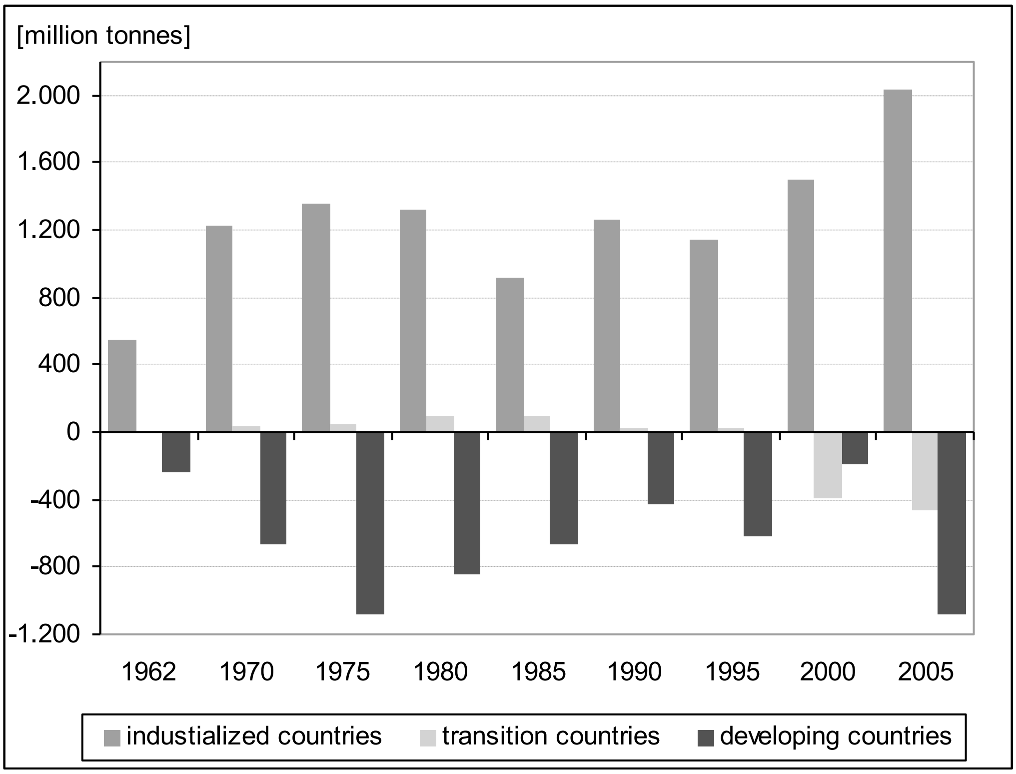
The last examples are trade profiles of some developing countries: Barbados as an example of an island with an important tourism and finance sector; it imported biomass (food) and fossil fuels. Benin imported biomass (food) to a large extent.



Source: own calculation based on UN Comtrade.

Figure 9: Material trade profile of selected countries, 2005; *China without water exports

When countries are grouped in the formerly so-called first, second and third world, respectively industrialized, transition and developing countries, it can be observed that industrialized countries as a group are net-importers while developing countries as a group are net-exporters (Figure 10). Again, missing data from developing and transition countries are mainly responsible for the fact that imports and exports are not balanced. In 2005, industrialized countries (net) imported around 2 billion tonnes in sum, while developing countries supplied more than 1 billion tonnes (probably more because countries were missing) and transition countries as a group supplied at least 500 million tonnes. Estimating the data of missing countries and extrapolating the years in-between, the resource flows from developing to industrialized countries approximately cumulated to around 75 billion tonnes between 1962 and 2005.



Source: own calculation, based on UN Comtrade

Figure 10: Physical trade balances by developing category, 1962 - 2005

The resource flow from developing and transition countries to developed countries consists first and foremost of oil; this is also reflected in Table 1, where the ten most important resource suppliers and consumers of the 45 years studied are listed. Due to the interpolation of data for missing years, the cumulative PTB represents an estimate. Nevertheless, it may be used to underline the relevance of the three main suppliers within the 'first world' (Australia, Canada and Norway) and the importance of oil and other fossil fuels exporters (Saudi Arabia, Venezuela, Iran and Russia). The largest net-exporter across the entire time period has been Australia with a share of global net-exports between 11 % and 15 %.

The most dominant net-importer is Japan with high net-imports during all the years. It is followed by the United States with increasing absolute net-imports and Germany with slightly decreasing net-imports. Emerging countries like South Korea and Malaysia are already among the ten dominant net-importers, with high growth-rates of net-imports.

Table 1: Main resource suppliers and demanders. Cumulative physical trade balances between 1962 and 2005

Resource suppliers (net export)	Cumulative PTB million tonnes	Resource demanders (net import)	Cumulative PTB million tonnes
Australia	-9,444.98	Japan	22,881.73
Saudi Arabia	-8,384.92	USA	14,225.59
Canada	-6,604.97	Germany	7,737.35
Russia*	-4,845.68	Italy	7,127.92
Venezuela	-4,837.89	South Korea	4,366.53
Brazil	-4,110.12	France	4,280.93

Indonesia	-3,873.92	United Kingdom	3,364.74
Norway	-3,257.32	Spain	3,208.67
Iran**	-3,053.96	Singapore	1,919.89
Kuwait	-2,464.94	Malaysia	1,000.98

Source: own calculation based on UN Comtrade; * Russia since 1995, **Iran missing data during years of war,

5. Possible areas of applications and outlook on further work

Knowing the physical dimension of international trade could be beneficial for improved analysis and better understanding of both its environmental and the socio-economic implications.

In general, physical trade flows are a constituent of material flow indicators like the domestic material input (DMI), total material consumption (TMC) or the resource productivity (e.g. GDP/TMR) to mention only three (e.g. OECD, 2008 a and b). These indicators quantify complementary aspects of the resource use of economies and can be used to formulate and monitor policies with an effect on dematerialization – on a national level but also on a global level. A precondition to deriving those indicators is the availability of data on the physical imports and exports. Without additional information on indirect flows (e.g. resource requirements or GHG emissions) linked to direct trade flows, the interpretation of PTBs with regard to environmental and related equity aspects remains limited (we will deal with these aspects in part II of this article).

Furthermore, physical dimensions of trade flows are needed to create trade indicators and indexes like terms of trade as well as transport statistics (UN Department of Economic and Social Affairs, 1998). The more complete and better known the physical dimensions are, the better country-specific or sectoral indicators can be calculated.

The presented method could help to implement physical accounts, particularly in countries with insufficient statistical capacities. It could further help to benchmark the different national accounts of physical trade on a world wide level.

In addition, our method could be used to provide the complete UN Comtrade-Database in physical units for further research on the physical implications of international trade (on regional or country-levels as well as on material or product levels). Further research is needed, for example on the links between international trade and development, and modelling is required on the impacts of growing resource use on a global scale.

In the beginning we pointed out that it is advisable to verify single trade flows with sectoral and/or regional statistics when analysing specific resource flows. The method presented provides a first global overview and helps to quickly identify the need for additional inquiries on sectoral and region specific trade flows and on internationally important process chains of specific products.

Within this study we did not include bilateral trade data, yet. Including them in the future will support identifying false data (see also UN Department of Economic and Social Affairs, 1998). Furthermore, it could help to validate the possible over- and underestimations caused by the applied method. It could moreover be used to estimate the physical trade of countries that did not at all report their trade to UN Comtrade.

This article introduced the method we developed and presented the empirical results. Further valuation and interpretation of the physical trade flows depends on the target questions and requires consideration of the relevant context[2]. To identify the global resource consumption of national economies, direct physical trade data is basically needed, but not sufficient. National extractions as well as indirect flows will be combined with trade-flows to allow cross-national comparisons of total material consumption in part II of this paper.

6. Conclusions

This article presented a method which can be used to calculate complete direct physical trade flows for all countries where at least monetary data are available. This method enables the material volume of global trade to be determined and compared with trade flows of different countries. The results for nine years between 1962 and 2005 show increasing global trade resulting in global direct material trade flows of about 10 billion tonnes in recent years, corresponding to a physical trade volume of about 20 billion tonnes (counting both imports and exports). The share from European Countries is declining, mainly in favour of Asian Countries. The dominant traded commodity in physical units is fossil fuels, mainly oil; almost half of the traded flows consist of fossil fuels.

By means of the physical trade balance the dominant resource suppliers and consumers have been identified. The principal resource supplier over the years has been Australia with a diverse material export structure; its exports are constantly high and still increasing since 1970. It is followed mainly by oil-exporting countries with varying volumes. As a region, Latin America, Australia and Central Asia are big resource exporters, mostly with growing absolute amounts of net-exports. In Africa, mainly South Africa is exporting. The largest net-importer has been Japan, significantly ahead of the United States and single European countries. Nevertheless, European countries as a whole have been the principal global net-importers (with the main exception of Norway), although with a declining global share, while the United States exhibits a rising share and Japan a constantly high share of global net imports. Emerging countries like the 'Tiger States' with a major industrial productive sector are growing net-importers, with some countries outranking European countries. In summary, with the major exception of Australia and Canada, industrialized countries are net-importers and developing countries and transition countries are net-exporters, but there are important differences within these groups.

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2 The different discourses to interpret and value physical trade balances as well as possible national goals for physical trade balances are discussed in Dittrich (2010). There are also results shown for physical trade per person as well as physical trade in relation to other relevant indicators.

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